Light Profile Decompositions from M31 to Virgo

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Light Profile Decompositions from M31 to Virgo

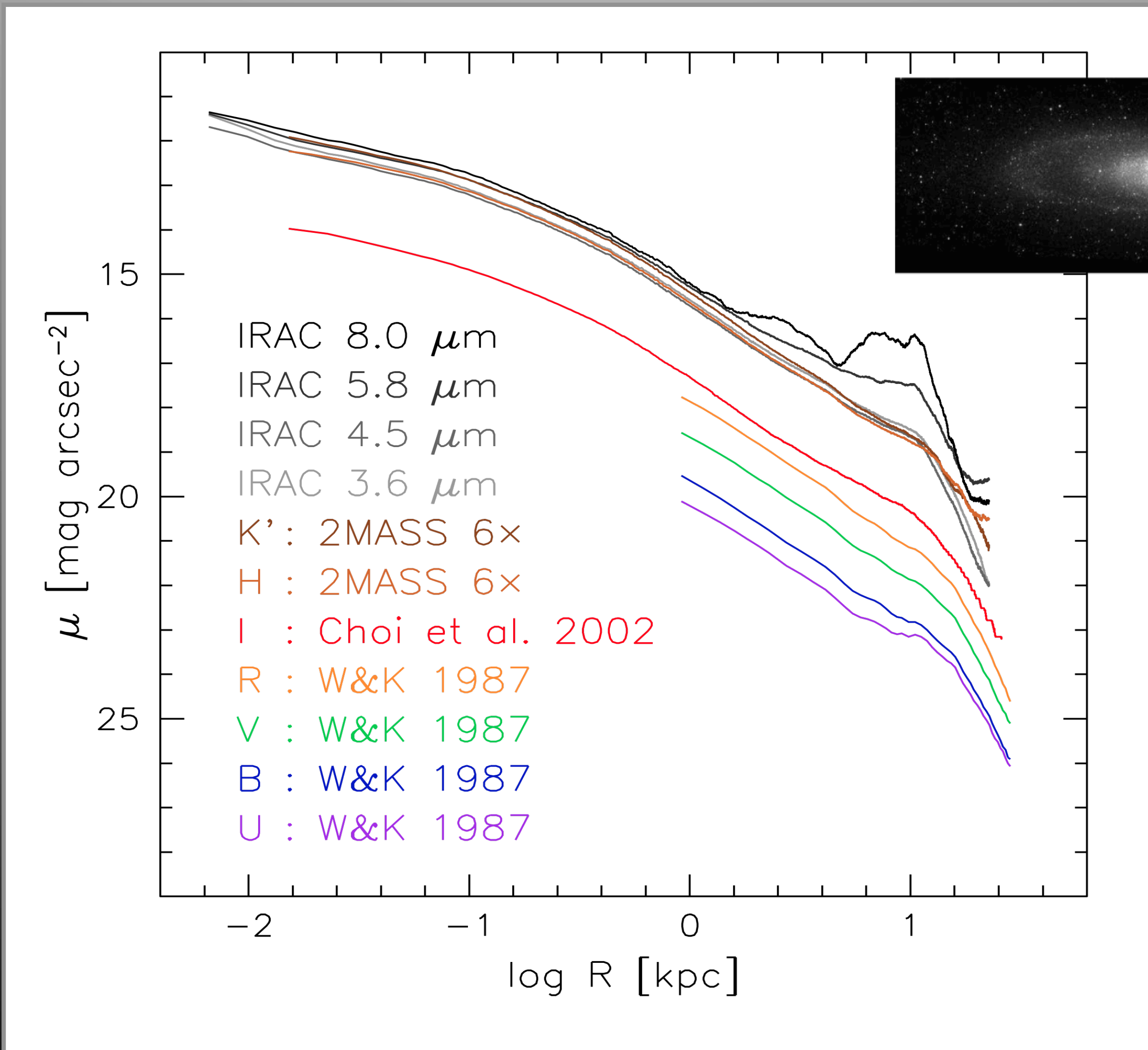
- Testing decomposition techniques on M31
- Testing 2D decomposition models with 2-component models of galaxies
- B/D decompositions of Virgo galaxies

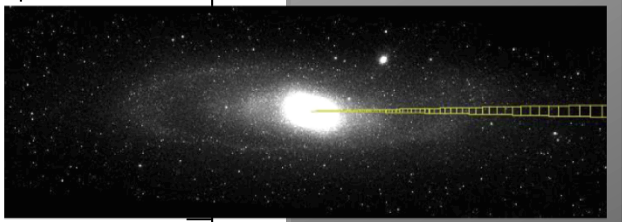
Model Decompositions

techniques:

- **1D NLLS (Levenberg-Marquardt)**
- **Bayesian / Markov-chain Monte Carlo (MCMC)**
- **2D NLLS (GALFIT), 2D MCMC (GIM2D)**
- ***bin vs unbin***
- ***minimization counts vs mag***
- ***features (spiral arm) clipping/modeling***
- ***cuts vs azimuthally-averaged SB profiles***

Available light profiles for M31





IRAC 3.6μm image

1D NLLS vs MCMC?

Courteau+2010

TABLE 2
BULGE/DISK DECOMPOSITIONS FOR M31

	Data	Method	Cut	n	R_e (kpc)	μ_e (mag arcsec^{-2})	ϵ_{bulge}	R_d (kpc)	μ_0 (mag arcsec^{-2})	ϵ_{disk}
A.	IRAC	MCMC	Maj	2.46 ± 0.09	1.09 ± 0.07	16.2 ± 0.10	--	5.09 ± 0.17	16.83 ± 0.07	--
B.	IRAC	NLLS	Maj	2.3 ± 0.3	1.0 ± 0.2	16.1 ± 0.3	--	5.4 ± 0.3	16.8 ± 0.1	--
C.	IRAC	MCMC	Min	2.01 ± 0.11	0.53 ± 0.05	15.47 ± 0.13	--	1.29 ± 0.09	16.49 ± 0.25	--
D.	IRAC	NLLS	Min	1.9 ± 0.6	0.5 ± 0.3	15.4 ± 0.7	--	1.3 ± 0.6	$16.4 \pm .15$	--
E.	IRAC	MCMC	MinMaj	2.18 ± 0.06	0.82 ± 0.04	15.77 ± 0.07	0.21 ± 0.01	4.71 ± 0.14	16.62 ± 0.05	0.74 ± 0.01
F.	IRAC	NLLS	AZAV	2.4 ± 0.2	1.10 ± 0.10	16.1 ± 0.10	--	5.8 ± 0.1	16.79 ± 0.02	0.74 ± 0.02
F*.	IRAC	MCMC	AZAV	1.66 ± 0.03	0.68 ± 0.01	15.34 ± 0.03	--	4.75 ± 0.01	16.41 ± 0.01	--
G.	IRAC	NLLS	AZAVmsk	2.2 ± 0.3	1.00 ± 0.10	16.0 ± 0.20	--	4.9 ± 0.1	16.70 ± 0.10	0.74 ± 0.02
H.	Choi02	MCMC	Maj	2.06 ± 0.06	0.91 ± 0.04	18.12 ± 0.08	--	5.69 ± 0.09	18.97 ± 0.03	--
I.	Choi02	NLLS	Maj	2.2 ± 0.3	1.12 ± 0.10	17.3 ± 0.2	--	6.4 ± 0.1	18.14 ± 0.04	--
J.	Choi02	MCMC	Min	1.85 ± 0.07	0.51 ± 0.02	17.62 ± 0.08	--	1.73 ± 0.05	18.99 ± 0.08	--
K.	Choi02	NLLS	Min	1.9 ± 0.2	0.53 ± 0.03	17.7 ± 0.1	--	1.68 ± 0.04	18.8 ± 0.1	--
L.	Choi02	MCMC	MinMaj	1.83 ± 0.04	0.74 ± 0.02	17.73 ± 0.05	0.28 ± 0.01	5.47 ± 0.08	18.91 ± 0.03	0.70 ± 0.01
M.	Choi02	NLLS	AZAV	2.00 ± 0.4	1.00 ± 0.30	18.2 ± 0.4	--	5.80 ± 0.10	19.0 ± 0.3	0.71 ± 0.02

2D (GALFIT) power…

Bulge:

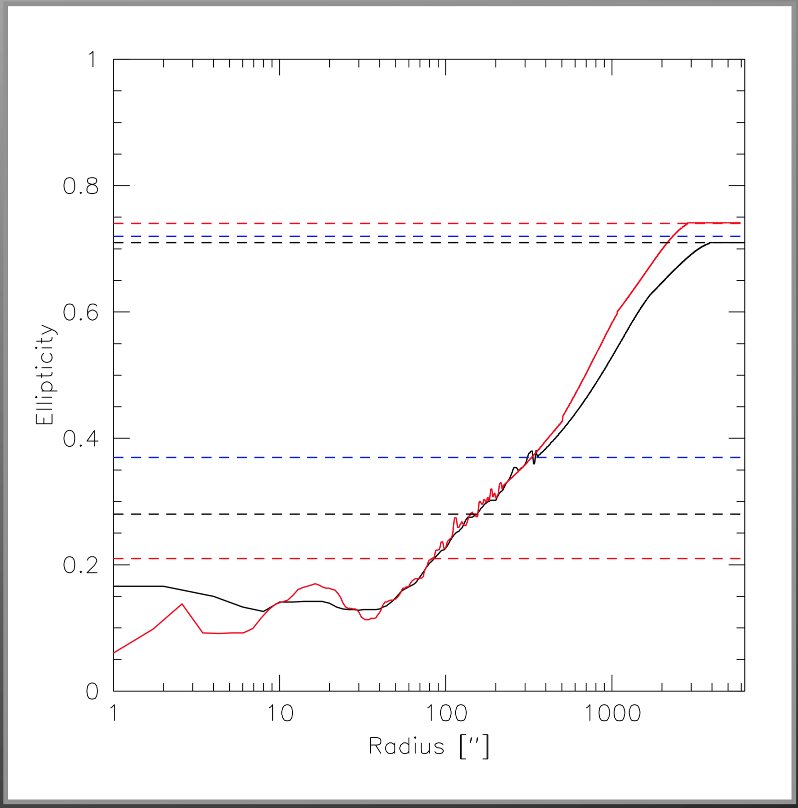
ε_{bulge} (2D) ~ 0.37

ε_{bulge} (1D) ~ 0.21

Disk

ε_{disk} (2D) ~ 0.73

ε_{disk} (1D) ~ 0.71



$\Delta(PA) \approx 20°$

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C.	IRAC	MCMC	Min	2.01 ± 0.11	0.53 ± 0.05	15.47 ± 0.13	--	1.29 ± 0.09	16.49 ± 0.25	--
D.	IRAC	NLLS	Min	1.9 ± 0.6	0.5 ± 0.3	15.4 ± 0.7	--	1.3 ± 0.6	$16.4 \pm .15$	--
E.	IRAC	MCMC	MinMaj	2.18 ± 0.06	0.82 ± 0.04	15.77 ± 0.07	0.21 ± 0.01	4.71 ± 0.14	16.62 ± 0.05	0.74 ± 0.01
F.	IRAC	NLLS	AZAV	2.4 ± 0.2	1.10 ± 0.10	16.1 ± 0.10	--	5.8 ± 0.1	16.79 ± 0.02	0.74 ± 0.02
F*.	IRAC	MCMC	AZAV	1.66 ± 0.03	0.68 ± 0.01	15.34 ± 0.03	--	4.75 ± 0.01	16.41 ± 0.01	--
G.	IRAC	NLLS	AZAVmsk	2.2 ± 0.3	1.00 ± 0.10	16.0 ± 0.20	--	4.9 ± 0.1	16.70 ± 0.10	0.74 ± 0.02
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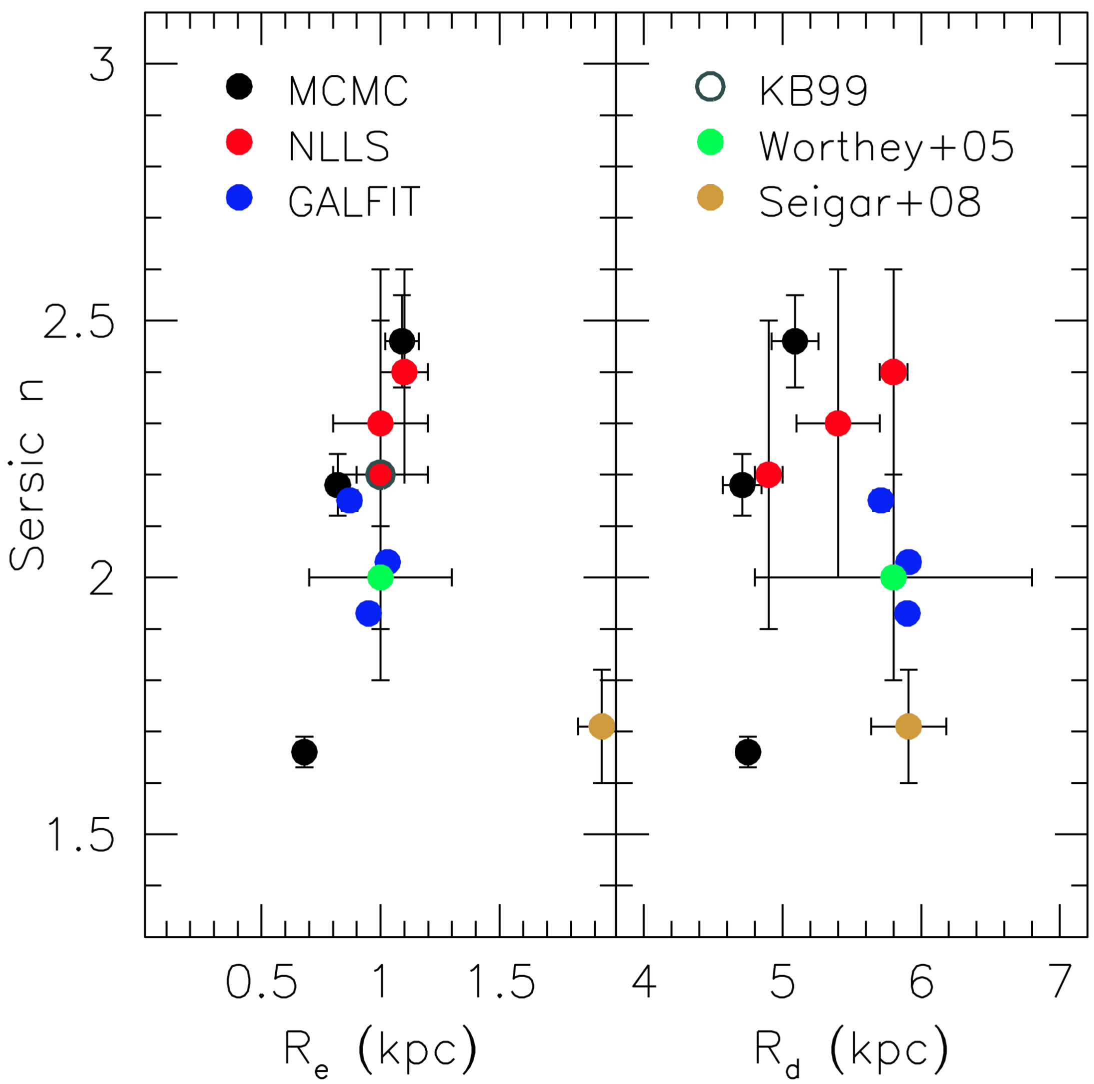
M.	Choi02	NLLS	AZAV	2.00 ± 0.4	1.00 ± 0.30	18.2 ± 0.4	--	5.80 ± 0.10	19.0 ± 0.3	0.71 ± 0.02

TABLE 3
GALFIT BULGE/DISK DECOMPOSITIONS OF THE M31 IRAC 3.6 μ IMAGE

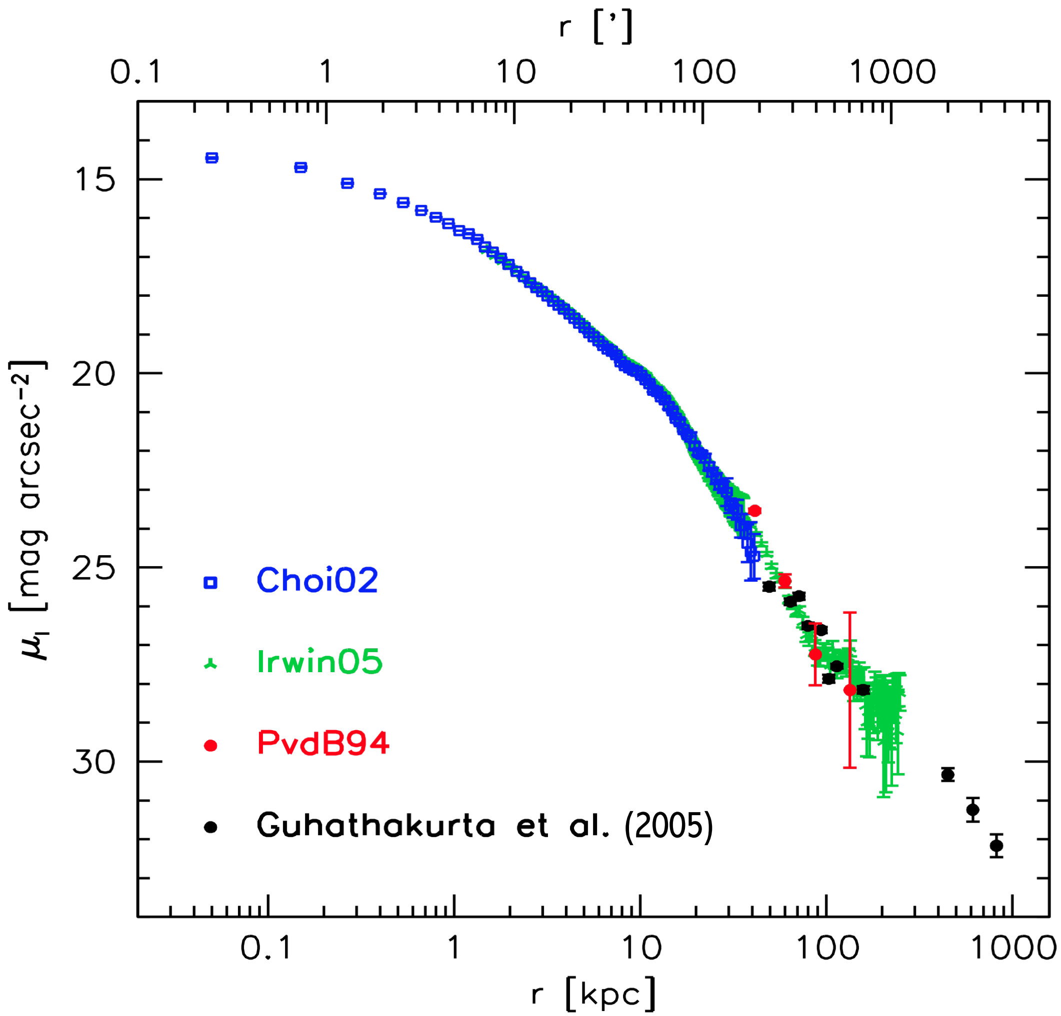
	Method	n	R_e (kpc)	μ_e (mag arcsec^{-2})	ϵ_{bulge}	R_d (kpc)	μ_0 (mag arcsec^{-2})	ϵ_{disk}
N.	Original Image	1.93 ± 0.00	$0.95\pm$	$16.06\pm$	$0.37\pm$	$5.90\pm$	$17.06\pm$	$0.72\pm$
O.	Masked Image	2.03 ± 0.00	$1.03\pm$	$16.18\pm$	$0.37\pm$	$5.91\pm$	$17.14\pm$	$0.72\pm$
P.	Forced ϵ_{bulge}, ϵ_{disk}	2.15 ± 0.00	$0.87\pm$	$16.87\pm$	$0.21\pm$	$5.71\pm$	$16.77\pm$	$0.74\pm$

Parameter range



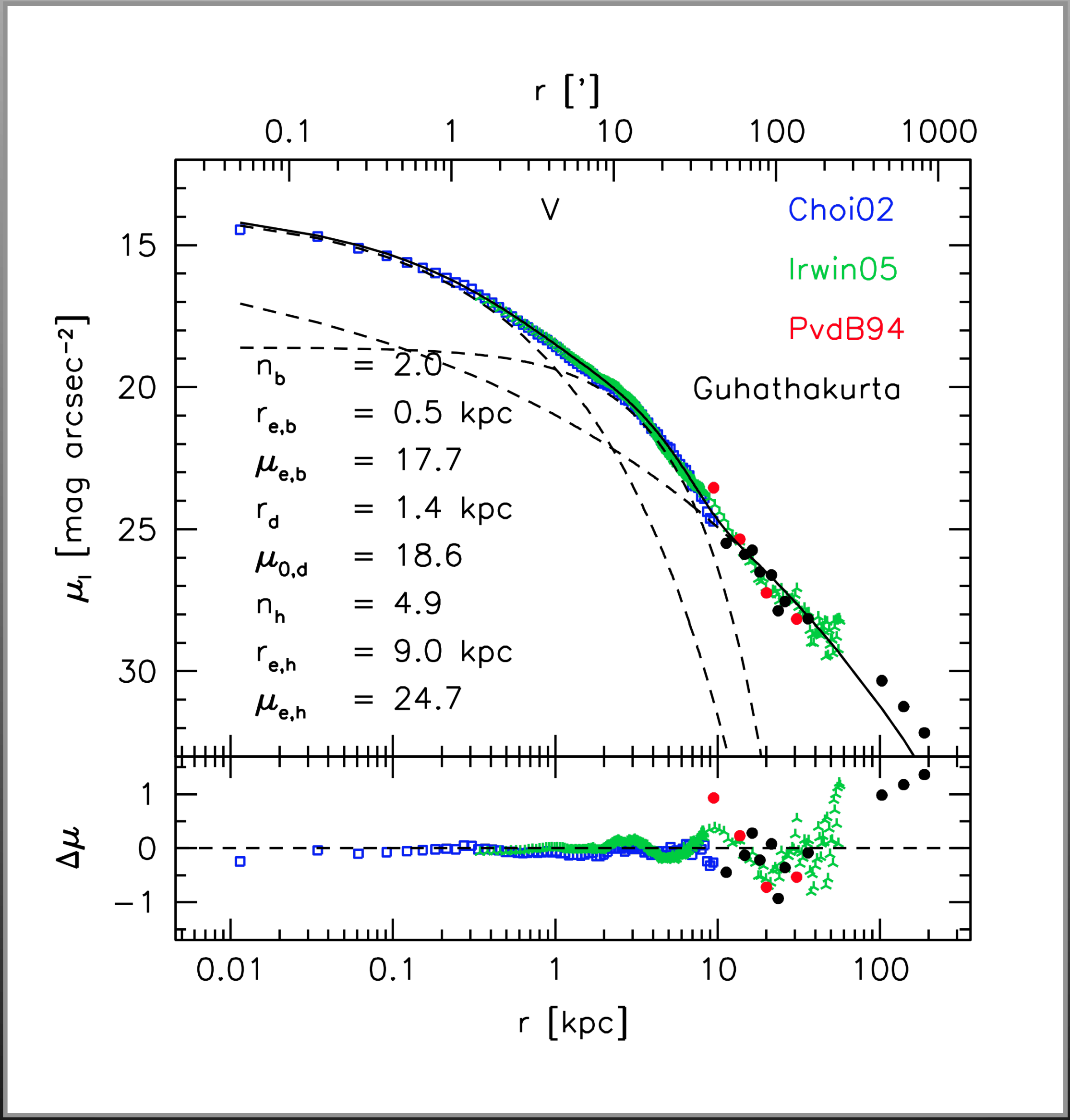
~20% parameter uncertainty

Halo Star Counts

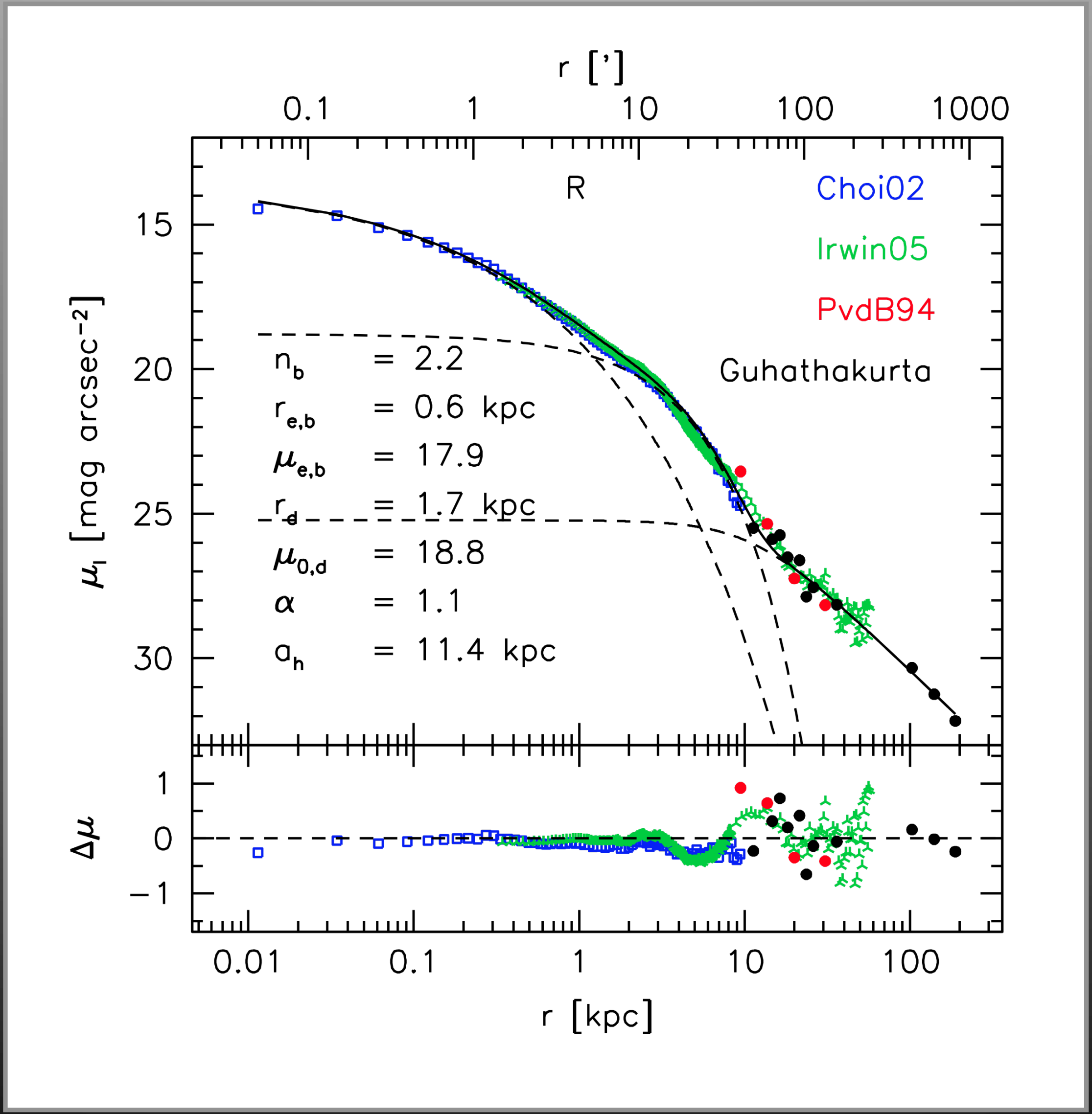


(minor axis)

Bulge / Disk / Sersic halo



Bulge / Disk / Power law halo



M31 B/D/H Decomps

TABLE 4
I-BAND COMPOSITE; BULGE/DISK/POWER-LAW FAINT

	Method	Cut	n	$R_{e,b}$ (kpc)	$\mu_{e,b}$ (mag arcsec^{-2})	R_d (kpc)	μ_0 (mag arcsec^{-2})	α	μ_* (mag arcsec^{-2})	a_h (kpc)
Q.	NLLS	Min/Bin	$2.20^{+.20}_{-.20}$	$0.60^{+.10}_{-.10}$	$17.90^{+.30}_{-.30}$	$1.70^{+.30}_{-.30}$	$18.80^{+.30}_{-.30}$	$1.10^{+.10}_{-.10}$	$27.70^{+.10}_{-.10}$	$11.40^{+0.10}_{-0.10}$
R.	MCMC	Min/Bin	$2.67^{+.11}_{-.11}$	$1.77^{+.05}_{-.05}$	$19.53^{+.07}_{-.07}$	--	--	$1.78^{+.29}_{-.30}$	$27.90^{+.08}_{-.08}$	$55.65^{+12.3}_{-12.6}$
S.	MCMC	Min/Bin	$2.72^{+.11}_{-.11}$	$1.75^{+.05}_{-.05}$	$19.52^{+.06}_{-.07}$	--	--	$1.77^{+.31}_{-.31}$	$28.05^{+.08}_{-.08}$	$55.47^{+12.7}_{-12.9}$
T.	MCMC	Min/Unbin	$1.77^{+.22}_{-.22}$	$0.45^{+.07}_{-.08}$	$17.50^{+.24}_{-.27}$	$1.35^{+.18}_{-.22}$	$18.48^{+.26}_{-.31}$	$1.11^{+.25}_{-.19}$	$27.90^{+.24}_{-.30}$	$3.05^{+.90}_{-.80}$
U.	MCMC	Min/UnBin	$1.89^{+.10}_{-.10}$	$0.51^{+.03}_{-.03}$	$17.66^{+.11}_{-.11}$	$1.54^{+.05}_{-.05}$	$18.72^{+.09}_{-.09}$	$1.14^{+.09}_{-.09}$	$28.32^{+.09}_{-.09}$	$6.60^{+1.22}_{-1.20}$
V.	MCMC	MinMaj/UnBin	$1.85^{+.05}_{-.05}$	$0.70^{+.02}_{-.02}$	$17.73^{+.05}_{-.05}$	$4.89^{+.06}_{-.06}$	$18.76^{+.02}_{-.02}$	$1.17^{+.06}_{-.06}$	$28.37^{+.08}_{-.08}$	$6.48^{+1.10}_{-1.11}$

TABLE 5
I-BAND COMPOSITE; BULGE/DISK/SÉRSIC FAINT

	Method	Cut	n	$R_{e,b}$ (kpc)	$\mu_{e,b}$ (mag arcsec^{-2})	R_d (kpc)	μ_0 (mag arcsec^{-2})	n_f	$\mu_{e,f}$ (mag arcsec^{-2})	$R_{e,f}$ (kpc)
X.	NLLS	Min†/Bin/Mag	$2.00^{+.30}_{-.30}$	$0.50^{+.10}_{-.10}$	$17.70^{+.20}_{-.20}$	$5.00^{+.70}_{-.70}$	$18.60^{+.30}_{.30}$	$4.90^{+0.80}_{-0.80}$	$24.70^{+2.0}_{-2.0}$	$9.00^{+13.0}_{-13.0}$
Z.	MCMC	MinMaj/Unbin/Cts	$1.79^{+.06}_{-.06}$	$0.69^{+.02}_{-.02}$	$17.71^{+.05}_{-.05}$	$4.90^{+.06}_{-.06}$	$18.76^{+.02}_{.02}$	$6.63^{+1.16}_{-1.15}$	$27.30^{+.72}_{-.70}$	$19.72^{+5.9}_{-5.4}$

Halo modeling

Bulge: 30% light $(R_e/R_d = .2)$

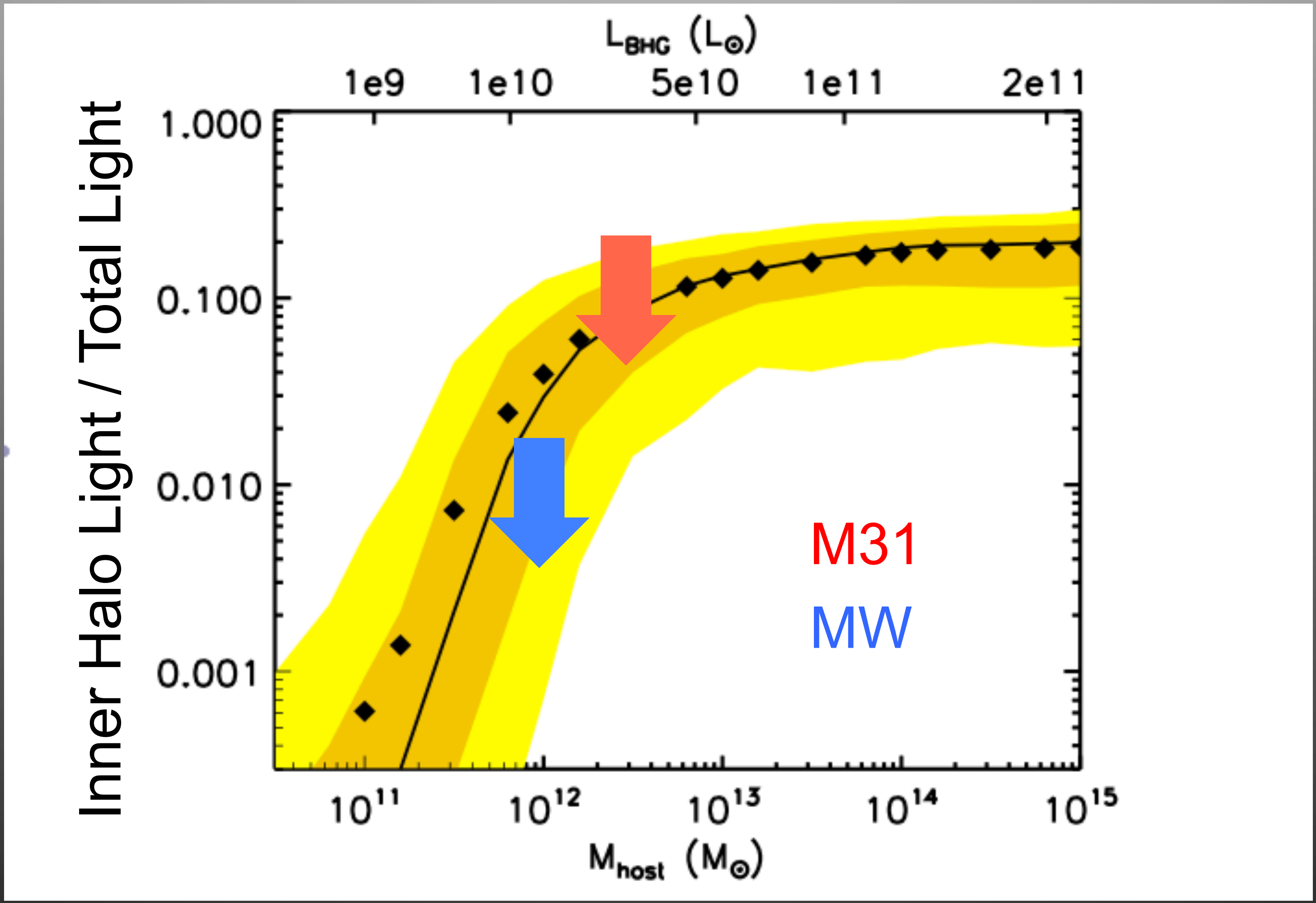
Disk: 70% light *B/D = .43*

Add halo* (27 mag arcsec^{-2})*:

Nucleus(0.05%) *Bulge (34%)*

Disk (47%) *Halo (19%)*

Fractional Halo Light



Purcell, Bullock, Zentner (2008)

Courteau & van den Bergh (1999)

1D / 2D simul^{n}s (after MacArthur etal 2003)

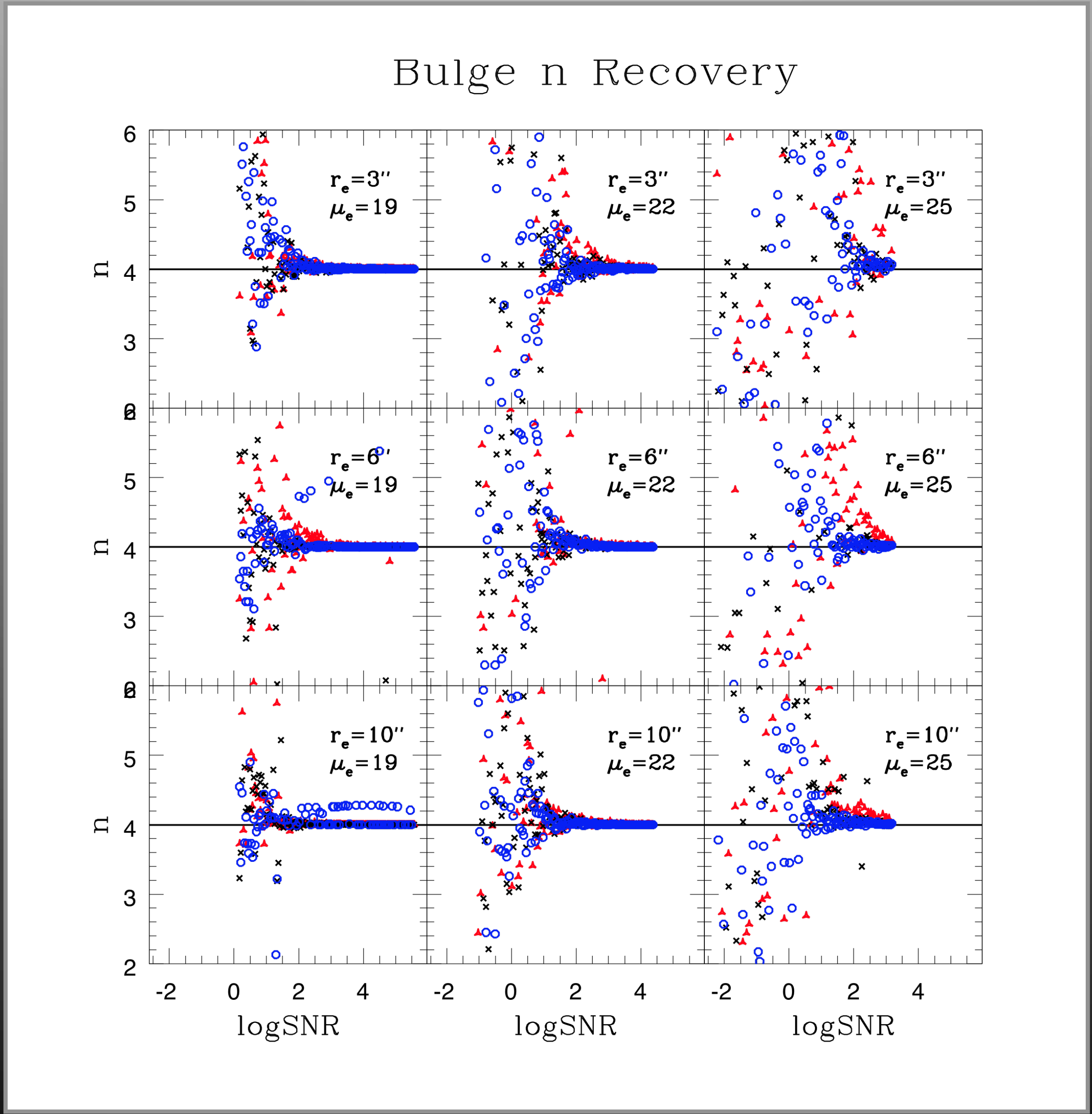
- create a suite of 2-component model galaxies (full range of structural parameters, ΔPA, SNR, seeing, …)

- Reduce images via 1D and 2D decomposition minimization techniques

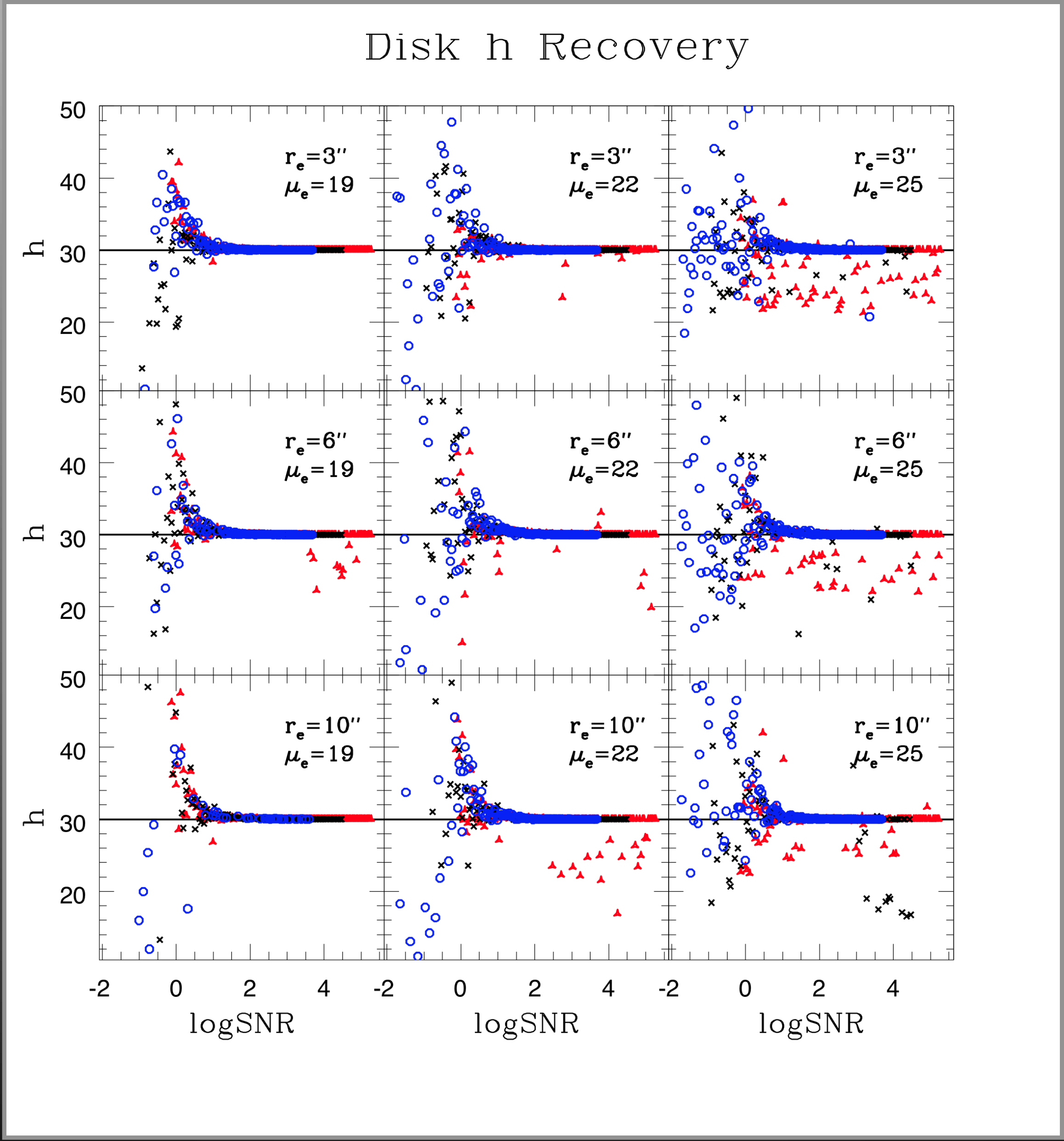
- test 2D (GALFIT)'s recovery

Define: $SNR = 10^{0.4 * (\mu_{sky} - \mu_{eff})}$

2D model recovery – *n*

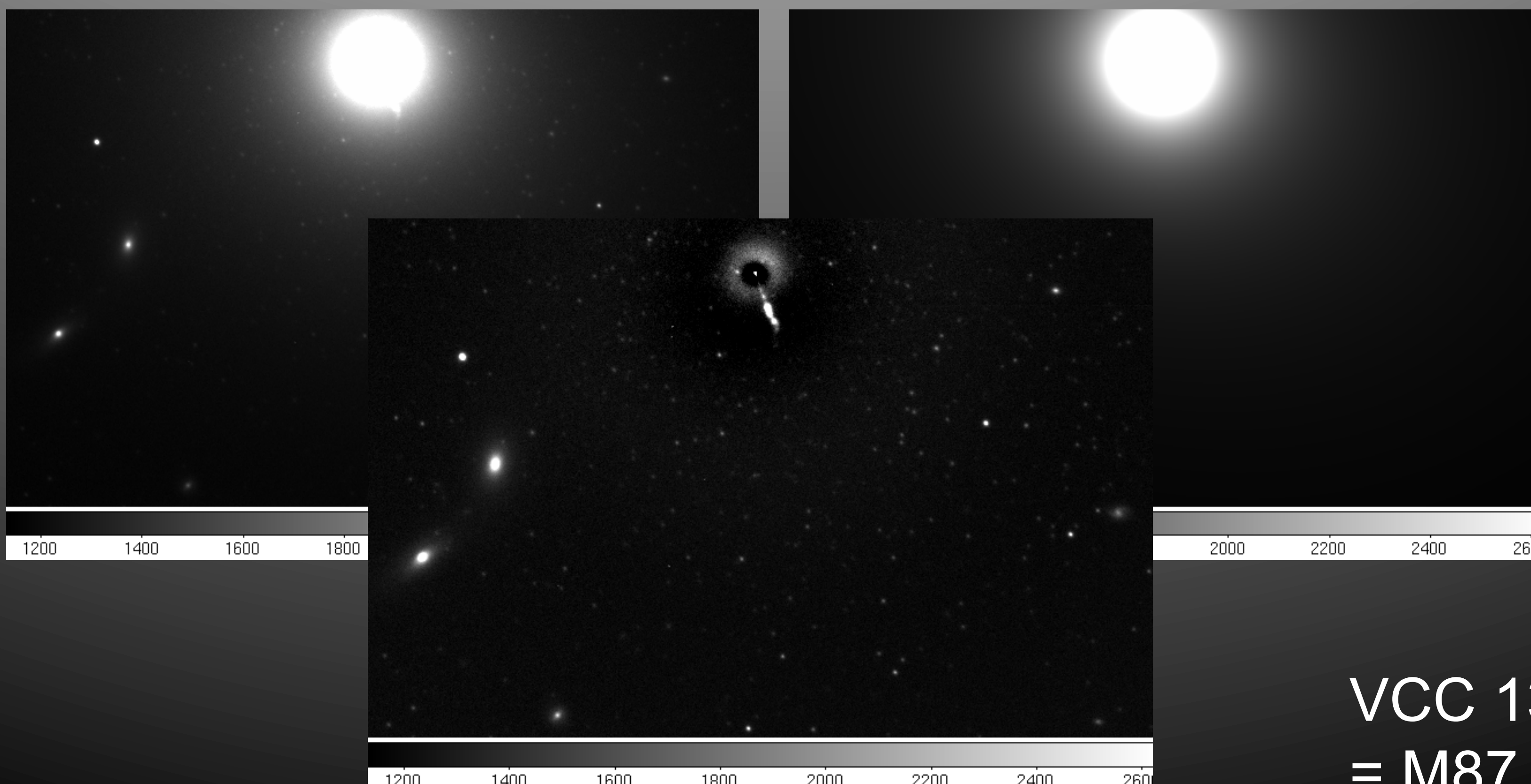


2D model recovery – R_d



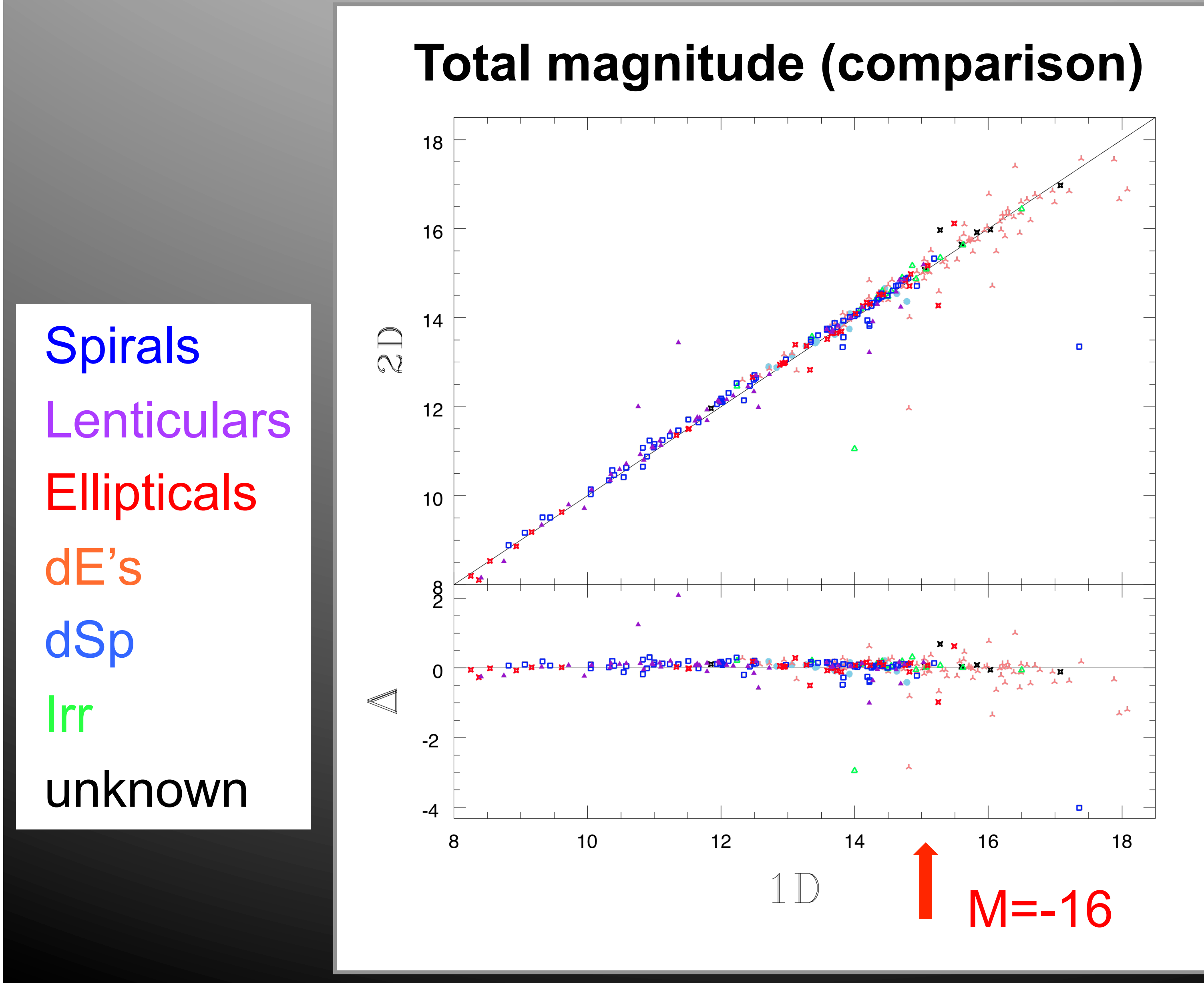
GALFIT analysis of 786 VCC/SDSS galaxies

- 1D isophotal fits (Courteau etal 1996)
  + 1D B/D decomps (McDonald etal 2009)
- 2D GALFIT (Peng etal 2002)

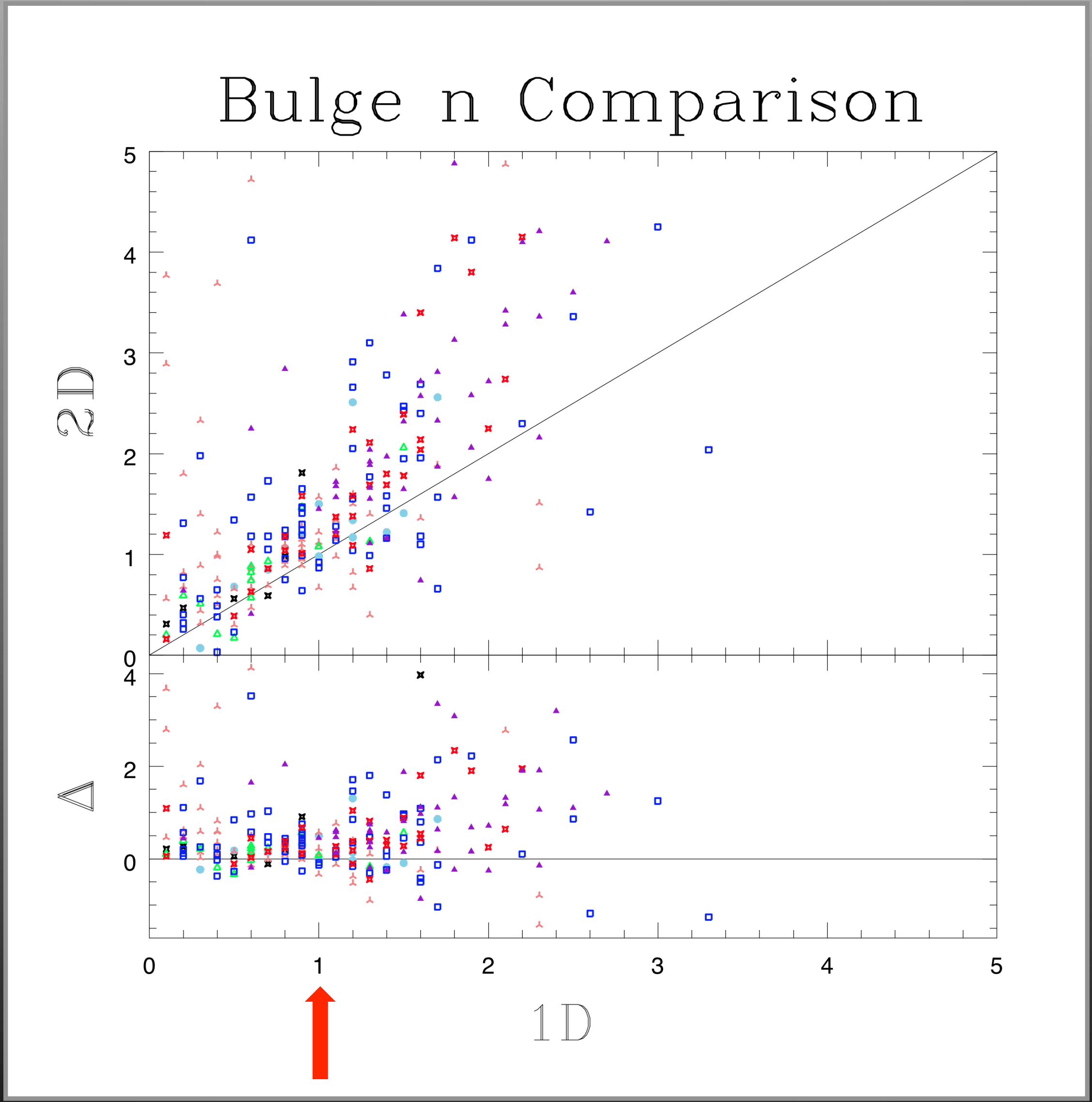


VCC 1316
= M87

1D vs 2D for 786 VCC/SDSS galaxies
(number reduces to ~300 gals for good GALFIT fits)



1D vs 2D for 786 VCC/SDSS galaxies
(number reduces to ~300 gals for good GALFIT fits)



1D vs 2D for 786 VCC/SDSS galaxies

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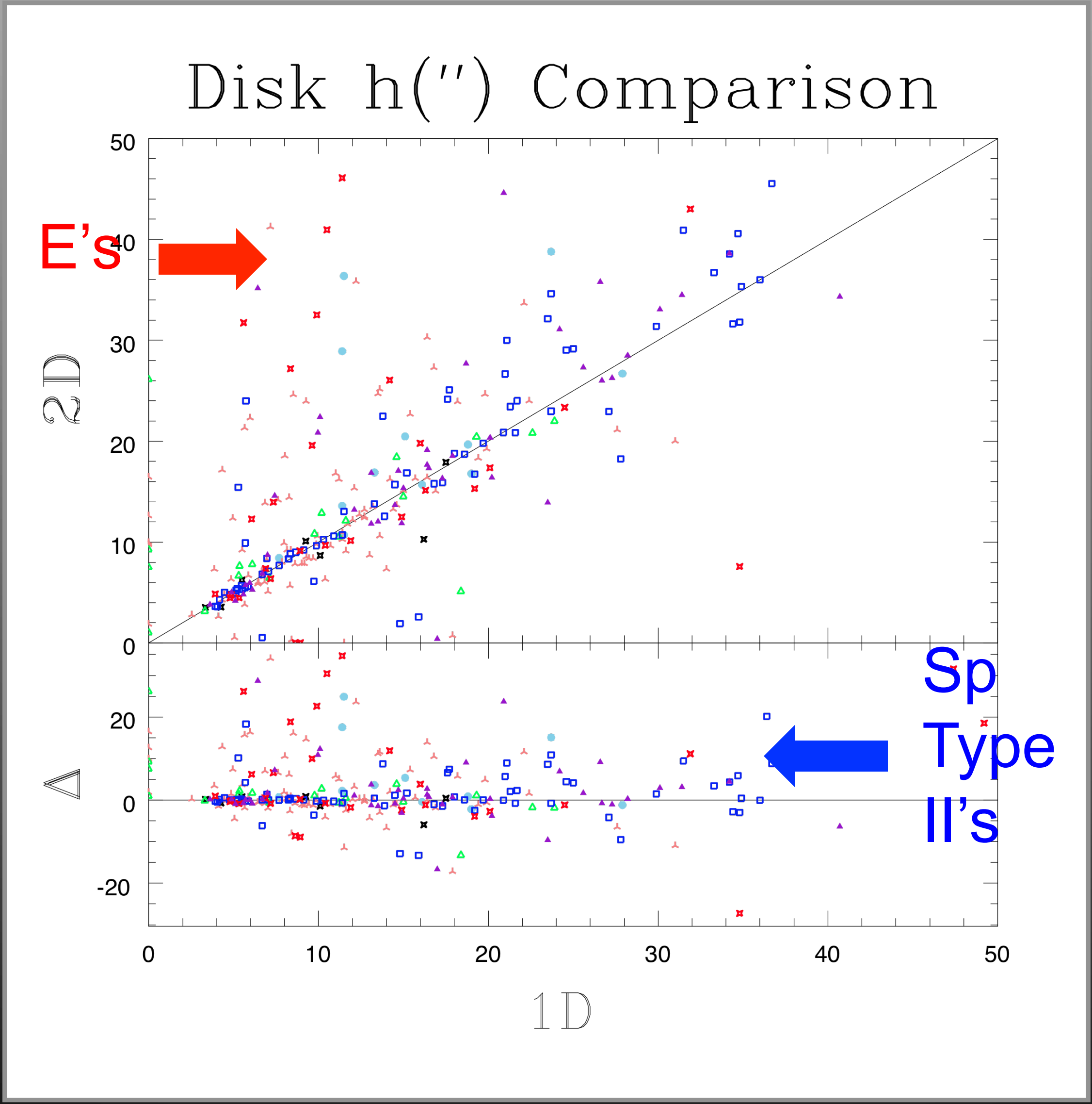
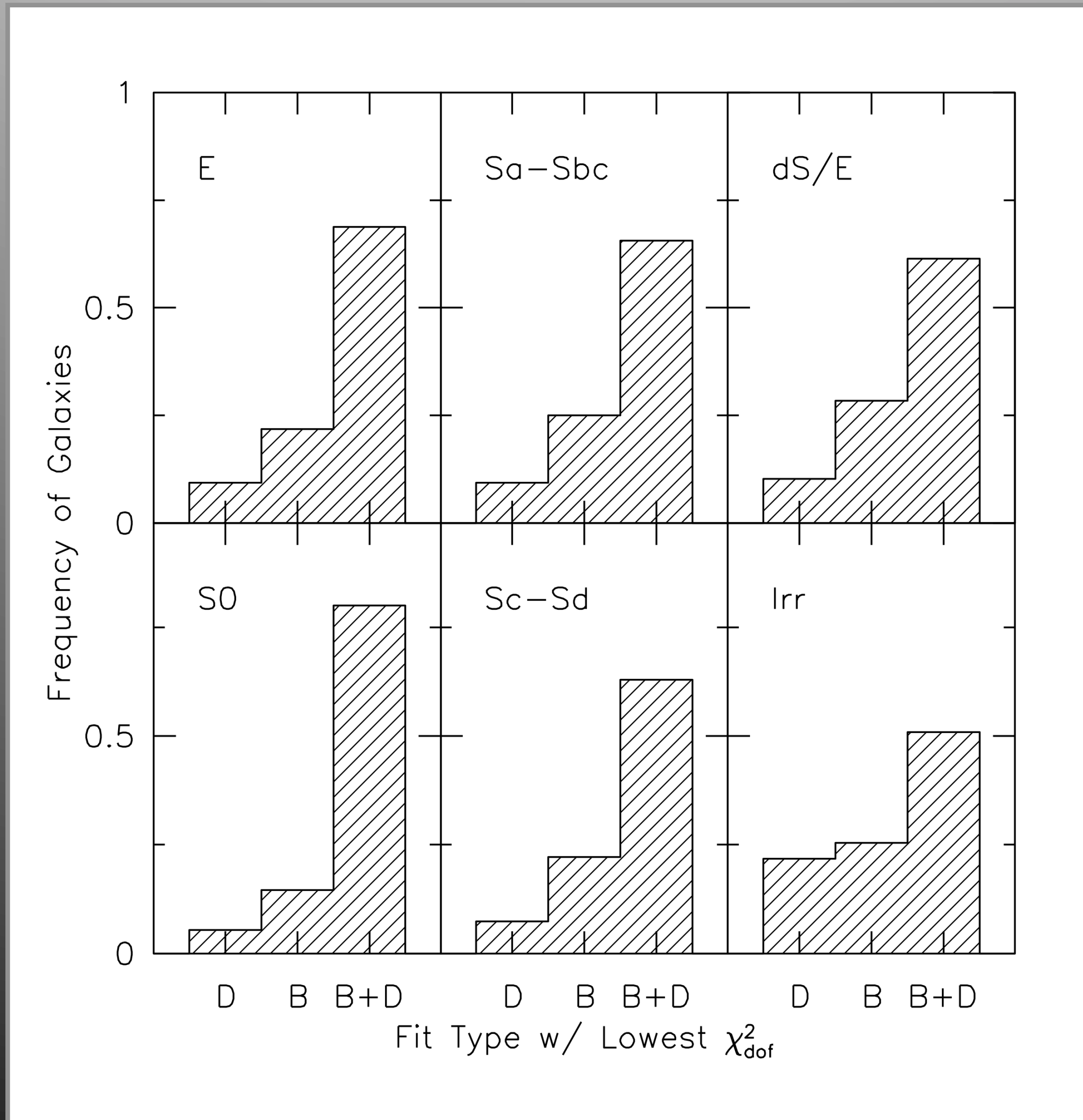
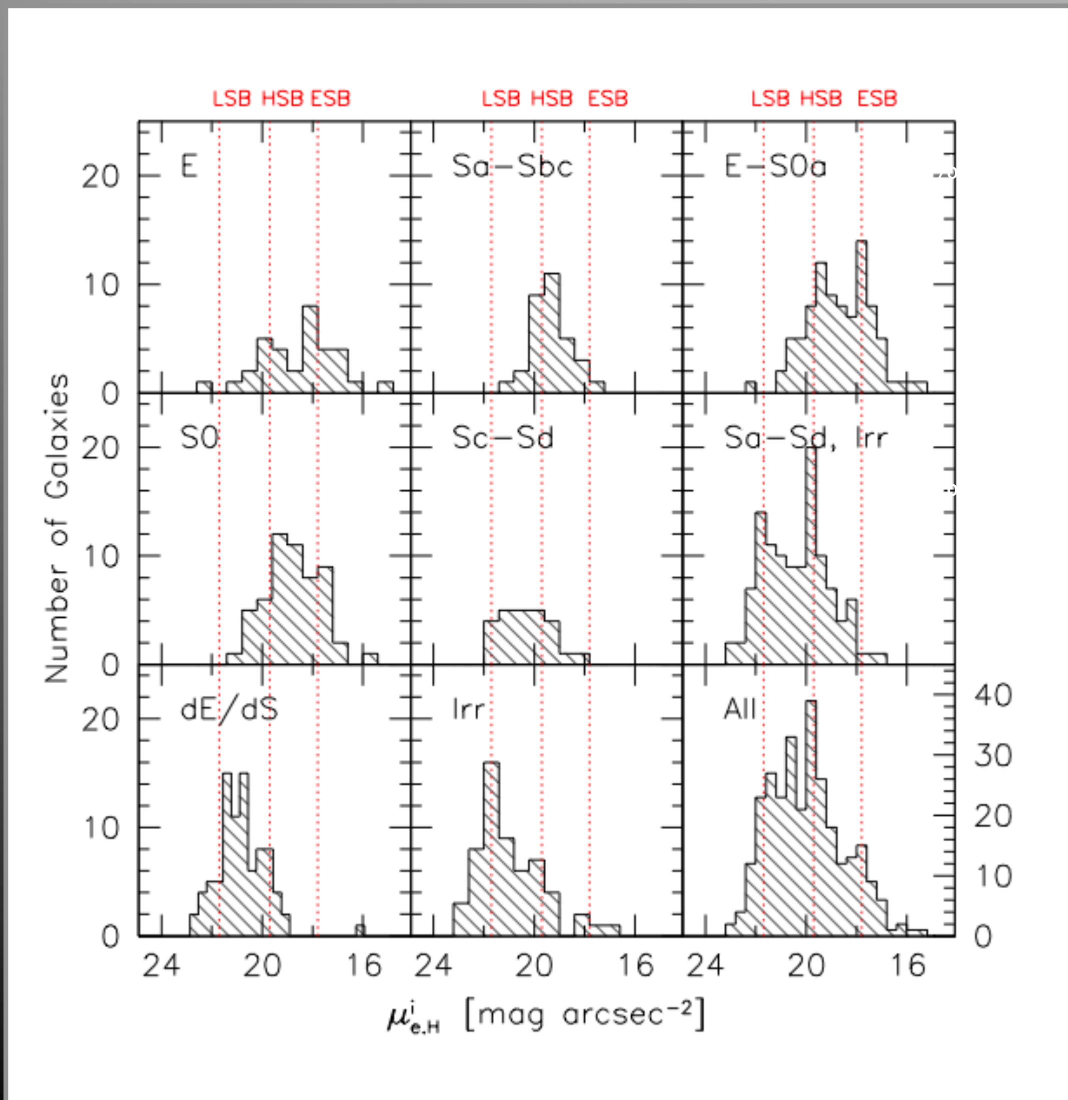


1D NLLS Decomps for 300 VCC galaxies



McDonald et al 2009; 2010

Non-parametric analysis BIMODAL μ_e distribution!



- ❖ Model independent μ_e for 286 VCC galaxies
  - – HSB-ESB=1.61
  - – LSB-HSB=1.61
- ❖ Most unexpected!
- ❖ McDonald, Courteau & Tully 2009, MNRAS

Conclusions

- Structural decomps of spiral galaxies accurate to ~20%
- 2D decomps ideal for treatment of variable PA
- MCMC ideal for proper treatment of errors (GALFIT uses NLLS)
  - need 2D GALFIT/MCMC

Conclusions …

- Halo significant below SDSS SB limit (*27 mag arcsec*$^{-2}$) ➡ NGVS!
- Sky determination critical
- Decomps for n>3 (cross-talk with sky) and with multi-components (strong covariances) AT RISK!